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PLANT COMMUNITY DYNAMICS IN WILKES LAND, ANTARCTICA

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Abstract: Antarctic cryptogamic communities are often remarkable for their uniformity in vegetation structure and floristic composition. Many typically exist as closely related units of vegetation in a continuum of variation which comprises an ecological mosaic of communities. Thus, specific associations of species tend to occur wherever a similar suite of environmental criteria prevails. However, many individual species are sensitive to minor differences in edaphic and microclimatic features of the habitat. This is commonly expressed in terms of sharp changes in species dominance and in community structure. The spatial dynamics of the vegetation is illustrated for the Site of Special Scientific Interest (SSSI) on Bailey Peninsula near Casey Station, Wilkes Land. Here, there exist some of the most extensive and best-developed plant communities in continental Antarctica. The vegetation associated with various topographical features was analyzed in contiguous quadrats along transects and its composition related to soil moisture, soil chemistry, and microclimate. The change in the distribution and abundance of the principal bryophyte and lichen species along these environmental gradients reflects their ecological requirements and tolerances.

1. Introduction

Excluding the Antarctic Peninsula, the terrestrial ecosystem of Bailey and Clark Peninsulas (Fig. 1) in the Windmill Islands, Budd Coast, Wilkes Land (approx. lat. 66°17′S, long. 100°32′E, the position of the Australian Casey Station), has some of the most extensive and best-developed plant communities in continental Antarctica. Here, many hectares of windswept ice-free terrain support a relatively diverse cryptogamic flora (SMITH, 1988a) which forms dense stands of macrolichens, while in moister more sheltered situations bryophytes are abundant and locally form closed stands of 25–50 m^2 comprising a moss turf up to almost 30 cm deep. For this reason representative areas of the two peninsulas have been designated Sites of Special Scientific Interest (SCAR, 1986). As part of a collaborative British Antarctic Survey-Australian National Antarctic Research Expeditions (BAS-ANARE) ecological program conducted at Casey Station in 1985–86 (SMITH, 1986) a detailed analysis of the vegetation of these areas was undertaken to develop a classification and ordination of the plant communities (SMITH, 1988a), and to provide an assessment of ecological patterns and species interactions. Ecophysiological and microclimate studies were also undertaken (SMITH, 1988b, c; KAPPEN *et al.*, 1989).

The distribution of individual species and of species assemblages varies markedly over often very short distances in response to changes in substratum (notably texture,

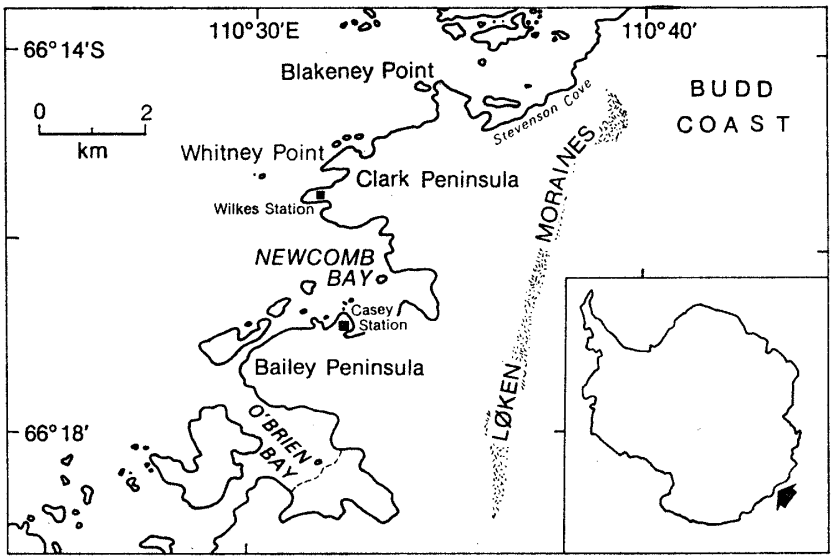

Fig. 1. Map of the Bailey Peninsula-Clark Peninsula area, Windmill Islands, Budd Coast, Wilkes Land.

microrelief, water availability) or microclimate (especially exposure to wind). Bryophytes are widespread with scattered colonies growing on soil amongst stones. However, closed stands of moss turf (*Bryum algens* possibly = *B. pseudotriquetrum*, *Ceratodon purpureus*, *Schistidium antarcticum*) are restricted to sheltered depressions and melt runnel margins which are deeply covered by snow in winter and well irrigated during the short summer by melting snow. In such situations, the liverwort *Cephaloziella exiliflora* is locally abundant. On dry, well-drained surfaces the mosses assume a cushion growth form, with *Schistidium* developing almost spherical colonies around a core of soil detached from the substratum, on dry rock ledges. Although mosses commonly overgrow gravel and stones on the ground and also occupy fissures in rock, they do not grow as lithophytes. On all leeward rock surfaces lichens (especially *Pseudephebe minuscula*, *Umbilicaria decussata*, *Usnea sphacelata*, and numerous crustose taxa) are usually abundant but the windward sides are totally unvegetated except in crevices, as a result of wind-blast abrasion by ice and soil particles. In contrast to the bryophytes, the majority of lichens grow on rock surfaces with some crustose taxa (*e.g. Acarospora chlorophana*, *A. gwynni*, *Lecidea phillipsiana*, *Rhizoplaca melanophthalma*) occurring along fissures, with hyphal wefts penetrating up to 1 cm into the rock and aiding exfoliation. A few species grow epiphytically on moss (*e.g. Usnea antarctica* on *Ceratodon purpureus*) or on other lichens (*e.g. Usnea antarctica* on *Umbilicaria decussata; Candelariella antarctica* possibly = *C. hallettensis*, *Pseudephebe minuscula*, *Umbilicaria decussata* on *Buellia frigida*), on dead moss (*e.g. Buellia grimmiae*, *Caloplaca athallina*, *Lecanora expectans*, *Rinodina olivaceo-brunnea*, *R. turfacea*), and occasionally on soil (*e.g. Caloplaca citrina*, *Candelariella antarctica*) (see Smith, 1988a).

The change in the distribution and abundance of the principal bryophyte and lichen species along these environmental gradients reflects their ecological requirements and tolerances. Examples of these spatial patterns within the Bailey Peninsula SSSI are presented here.

2. Methods

Sites exhibiting marked floristic change in relation to specific environmental criteria were selected for analysis. At each site a line transect was laid out and the percentage cover of all plant species was recorded in successive contiguous quadrats along the line. The length of transect and size of quadrat (25×25 cm, 10×10 cm, or 2×10 cm) depended on the scale of the gradient at each site. The distribution of the principal species at selected sites is presented here as histograms of cover abundance. A proportion of the moss *in situ* at any site is usually moribund, and this is recorded as dead moss. At some sites, relative exposure was determined as rate of loss (expressed as mg h^{-1}) of deionized water from 50 mm^2 wicks protruding from the lids of 10 m*l* evaporimeter tubes exposed at the soil or vegetation surface. Soil and moss turf or underlying peat were sampled at intervals along some transects for physical and chemical analyses. Moisture content was determined for fresh samples dried at 80°C. Fresh samples were diluted with deionized water and pH was determined on the stiff slurry using a portable pH meter and electrode.

The concentrations of elements were determined spectrophotometrically on air dried samples: for extractable Na, K, Ca, Mg, and Mn using ammonium acetate (pH 7) as the extractant, for extractable P using Truog's solution, for extractable Fe and Al using 3% oxalic acid, for extractable inorganic N as NH_4-N and NO_3-N, using 6% potassium chloride and water, respectively, total elements were extracted using the sulfuric acid-hydrogen peroxide digestion method and total organic N using the Kjeldahl method (see ALLEN, 1989, for methodologies).

3. Results

3.1. Community structure in relation to wind exposure

Site 1 (Fig. 2) is one of many low knolls composed of small pebbles often exceeding a meter in depth. These represent former Adélie penguin (*Pygoscelis adeliae*) nest sites which were abandoned probably several thousand years ago (see LLANO, 1959). They occur particularly around the 30 m contour and may have been abandoned when coastal ice fields increased in extent and prevented overland access from the sea. Subsequently, the margin of the polar ice cap retreated resulting in isostatic uplift of the low coastal areas. Soil below this level is often rich in silicious sponge spicules, implying that it had once been below sea level. Beneath the surface of these knolls the stones are embedded in a pinkish-brown relictual guano soil containing abundant fragments of egg shell and bones. Many of these pebble mounds are now densely colonized by *Usnea sphacelata* and other lichens. These sites must be of considerable antiquity since, in such a dry climate, it would take a very long time for the substratum to be leached of its thick guano accumulations and the sites rendered favorable for colonization by these nitrophobous lichens. The dense cover of macrolichens, notably *U. sphacelata*, on the leeward slope and also in a small depression on the windward slope and rockier, and therefore slightly sheltered level ground beyond the knoll, is demonstrated both by their cover values and biomass, which is exceptionally high (>900 g dry weight m^{-2}) on the leeward slope. Exposure, in terms of mean evaporation, along the transect over 10 h

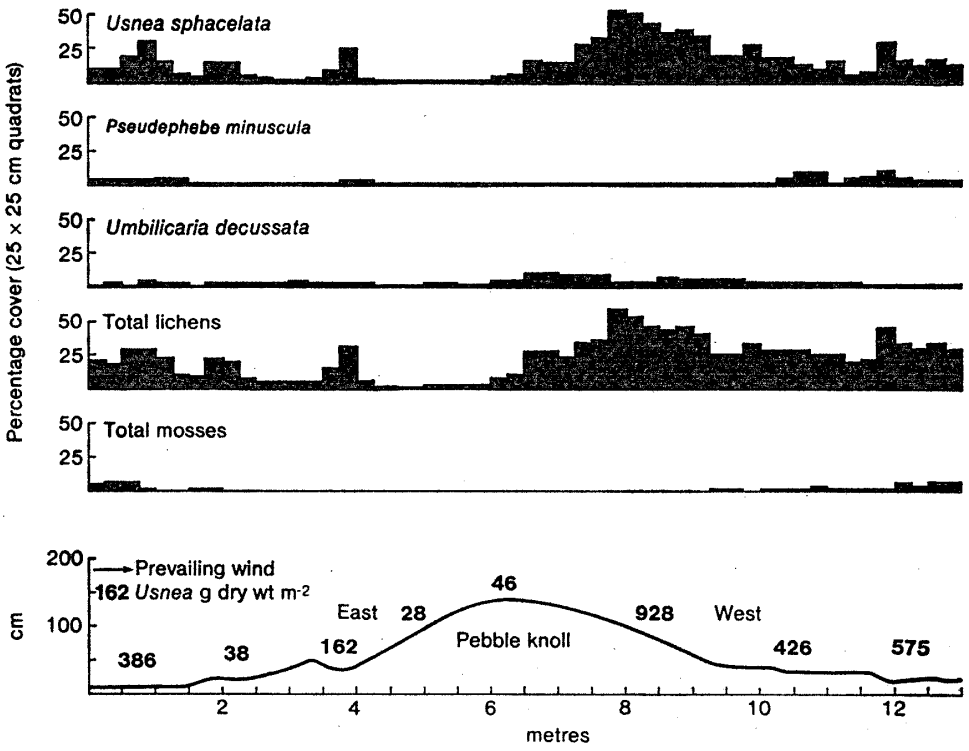

Fig. 2. Site 1. Distribution and percentage cover of principal species along an exposure gradient on a pebble knoll, once the nesting site of Adélie penguins. Change in the biomass of Usnea sphacelata *is also shown at intervals along the transect.*

Table 1. Relative exposure at substratum-vegetation interface in terms of water loss from evaporimeters.

Site	Mean evaporation (mg h^{-1})	
	30 Dec. 1985 (13.5 h)	31 Dec. 1985 (9.7 h)
Site 1 (see Fig. 2)		
Exposed unvegetated lower windward slope		67.4
Knoll crest, with sparse *Usnea sphacelata*		102.6
Sheltered vegetated (*U. sphacelata*) leeward slope		12.2
Site 2 (see Fig. 3)		
Ceratodon-Schistidium zone		12.3
Pseudephebe zone		28.6
Usnea zone		63.4
Margin of *Umbilicaria* and *Buellia frigida* zones		86.2
Unvegetated crest of rock		114.6
Site 4 (see Fig. 5)		
Crest of knoll: unvegetated soil/stones	60.3	98.2
Usnea sphacelata	52.2	93.2
Windward slope: unvegetated soil/stones	47.4	74.9
Narrow terrace near base of windward slope:		
Back, *Rinodina-Ceratodon*	46.4	74.9
Front, unvegetated	47.8	75.1
Below knoll: convoluted *Ceratodon-Bryum* turf		
Crest	26.7	37.6
Hollow	16.0	23.0
Continuous stand of *Schistidium*	17.0	22.6

Table 1. (Continued)

Site 5 (see Fig. 6)		
Windward rim of hollow: unvegetated soil/stones	56.7	102.1
Usnea sphacelata, surface	55.4	93.5
U. sphacelata, below canopy	45.2	70.9
Schistidium	49.8	81.6
Slope of hollow: convoluted *Ceratodon* turf	34.8	68.9
Hollow: convoluted *Ceratodon* turf, crest	18.8	33.5
NW face (sun)	26.9	67.6
SE face (shade)	10.1	10.8
Usnea antarctica, surface	42.0	65.0
below canopy	12.0	13.9
Weather conditions		
Air temperature (°C)	−1° to −4°	−2.5° to −1°
Sunshine (h)	3.3	17.4
Relative humidity (%)	65–58–65	52–68
Windspeed (m s^{-1})	1–4	1.5–5
Wind direction	N-NW	NW-NE

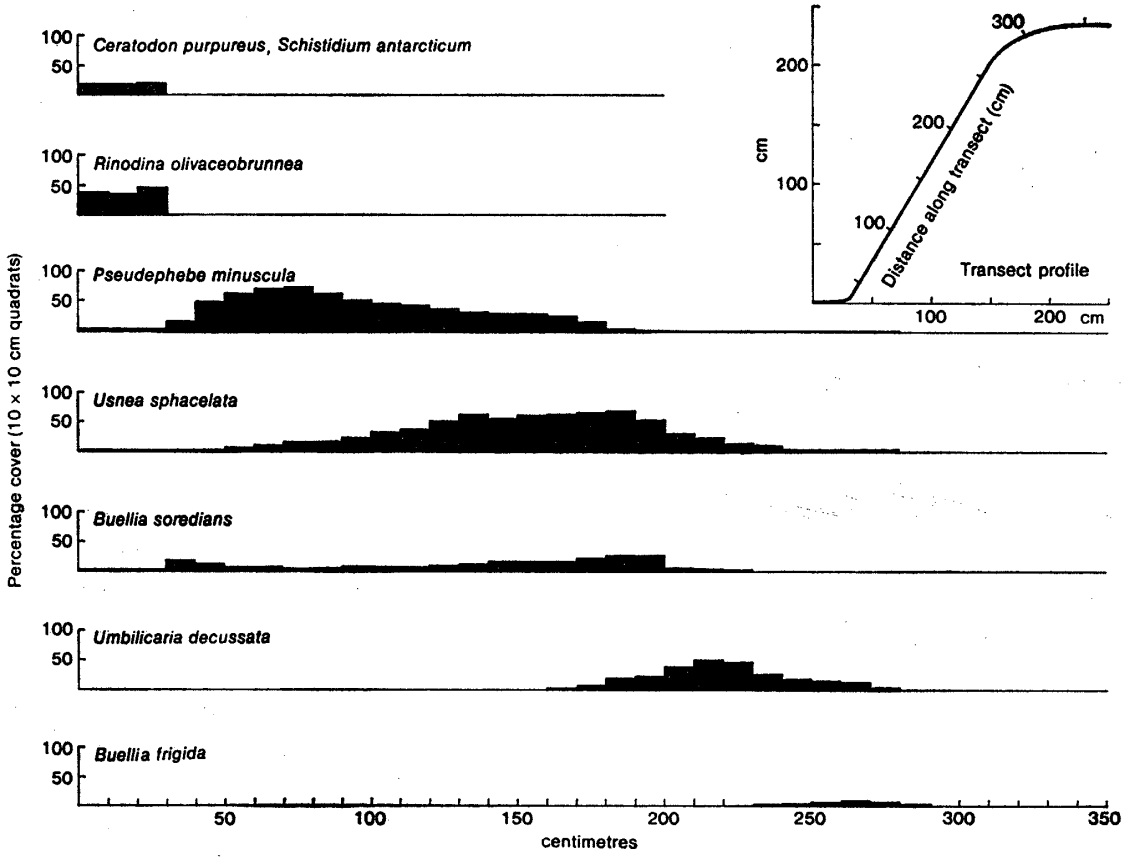

Fig. 3. Site 2. Distribution and percentage cover of principal species along an exposure-snow depth gradient on a steep leeward rock face.

on 31 December 1985, is given in Table 1.

Rock faces and boulders commonly exhibit small-scale zonation of species. The disposition of lichens on a steep leeward rock face is shown for Site 2 (Fig. 3). The vegetation is arranged in a series of narrow intergrading zones, with the dominant species in each being determined by the degree of exposure and presumably also by the depth of snow during winter, and the subsequent duration of moisture available to the plants. Thus the intermittently moist stony soil at the base of the rock is dominated by the moss *Ceratodon purpureus* encrusted with *Rinodina* cf. *olivaceobrunnea*. The rock face is successively dominated by *Pseudephebe minuscula*, *Usnea sphacelata*, with an increasing understorey of *Buellia soredians*, *Umbilicaria decussata*, and finally *U. decussata* with *B. frigida* on the uppermost part where thalli are small and wind-abraded. *B. frigida* extends to within 1–2 mm below the leeward side of the crest of the rock. The wind-blasted crest of the rock is devoid of vegetation. Each zone is representative of a different community or nodum distinguished in subjective and objective classifications of the region's vegetation (Smith, 1988a). Similar zoning of species is commonly seen on the lee of large boulders in windswept areas. Here bands of *B. frigida*, *Pseudephebe* and/or *Umbilicaria* and *Usnea* occur over a distance of 10–20 cm from the most exposed part immediately on the sheltered side of the rock crest, to the more sheltered part lower down. Exposure data (as mean evaporation) along the transect on 31 December 1985 are given in Table 1.

3.2. Community structure in relation to wind exposure and moisture

Site 3 (Fig. 4) is typical of boulder-fields on level ground below melting snow patches where water up to 20 cm deep accumulates between boulders. The floor of these pools may be covered by an algal mat, predominantly of *Phormidium* sp., while the frequently submerged lower walls of the rock are covered by a loose, crumbly grey crustose lichen (possibly an ecotype of *Buellia soredians*). It also extends above the water-line together with a clearly defined band of *Umbilicaria aprina* which grows from up to 10 cm above to precisely the level of the water-line. This zone gives way sharply to a series of narrow intergrading zones dominated successively by *Usnea sphacelata*, *Pseudephebe minuscula* and *Buellia soredians*, *Umbilicaria decussata*, and finally *Buellia frigida* as exposure increases up to and over the crest of the boulders. In hollows between boulders where water may lie only very temporarily, *Ceratodon purpureus* and *Schistidium antarcticum* form closed turves, often with epiphytic mats of *Cephaloziella exiliflora*. Where the moss surface is convoluted, the ridge crests are typically colonized by *Rinodina olivaceobrunnea*.

Site 4 (Fig. 5) extends from the top of a windswept *Usnea sphacelata*-dominated pebble knoll similar to that at Site 1 to a relative sheltered *Schistidium antarcticum*-dominated hollow kept wet during summer by the outflow from a small melt lake. Although the exposed flat knoll crest is extensively covered by macrolichens, the windward slope is almost free of vegetation. The occasional presence of *Xanthoria candelaria* and *Prasiola crispa* beneath pebbles indicates nitrogen enrichment from groups of south polar skuas (*Catharacta maccormicki*) which bathe in the lake and use the nearby knoll as a roost. Near the foot of the slope are two narrow soil-covered terraces, which quickly accumulate snow during summer snow falls. These support short coalesced

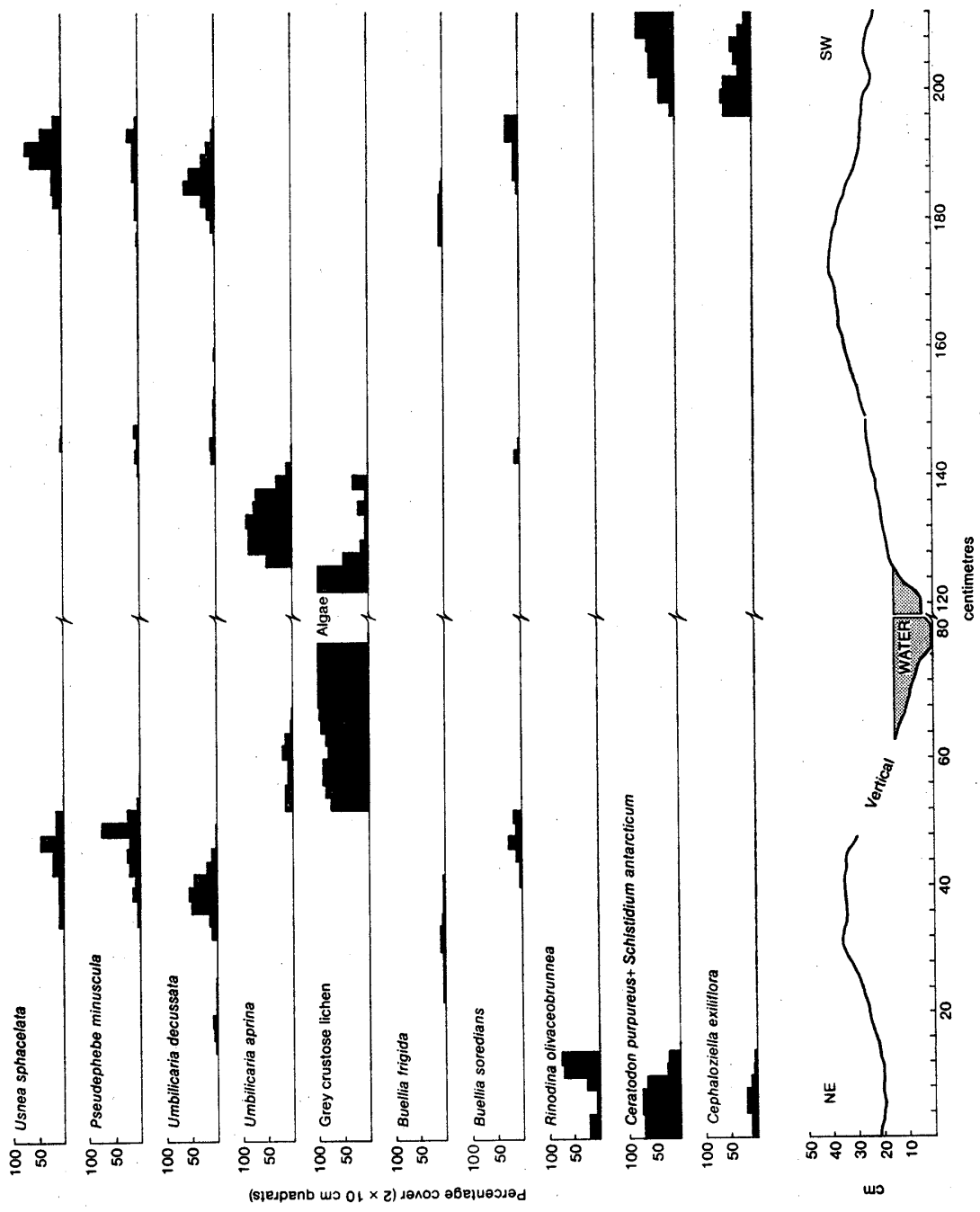

Fig. 4. Site 3. Distribution and percentage cover of principal species along an exposure-moisture gradient across a windswept boulder-field with temporary inter-boulder pools of melt water.

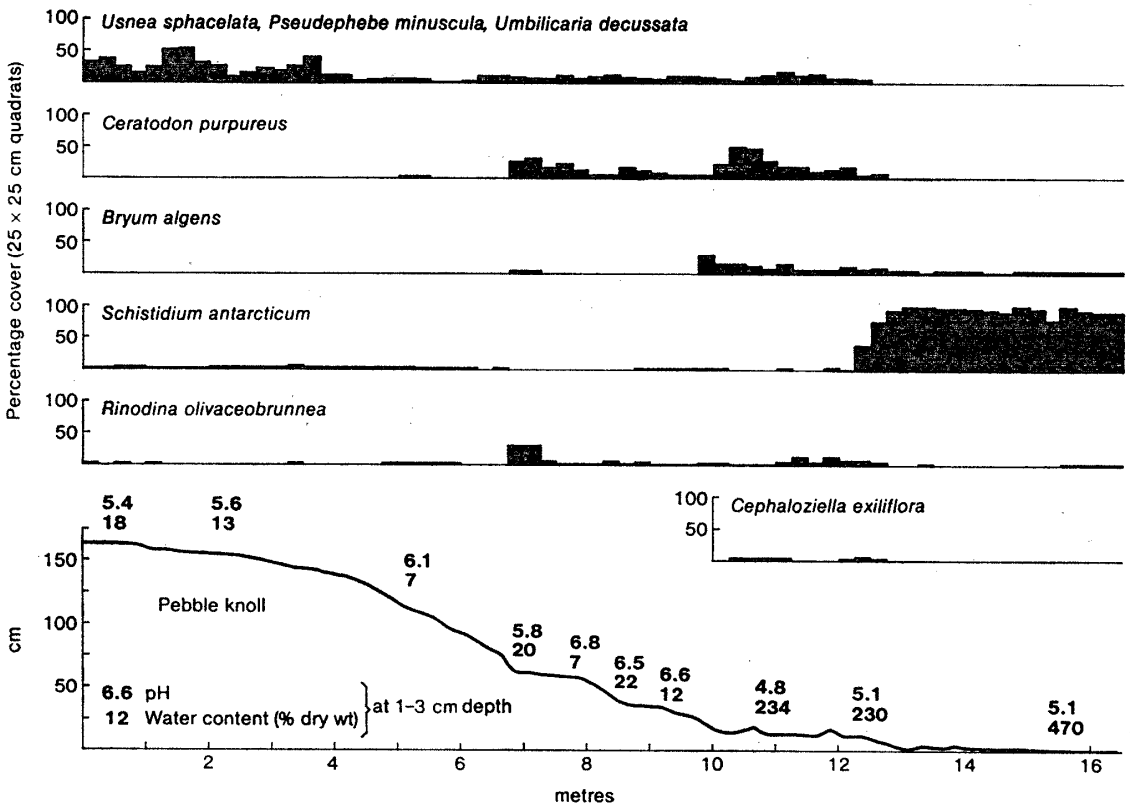

Fig. 5. Site 4. Distribution and percentage cover of principal species along an exposure-moisture gradient from the crest of a pebble knoll to a hollow with the outflow from a melt lake. Soil pH and water content are also shown at intervals along the transect.

turves of *Ceratodon purpureus* which are extensively covered by *Rinodina olivaceobrunnea* where snow lies deepest. On the lower stony ground zones of *Bryum algens* and mixed *Bryum algens*, *Ceratodon* and *Cephaloziella exiliflora* predominate in the moist but well-drained ecotone bordering the saturated *Schistidium*-dominated hollow.

Soil pH and moisture content at 1–3 cm depth along the transect are shown in Fig. 5. Horizontal and vertical changes in the soil chemistry are shown in Table 2. The high levels of Ca and P result from leaching from both present skua guano and sub-fossil penguin guano within the knoll. Although nutrients do not appear to be limiting and are, for some elements, in high concentrations, the development of more complex communities in these fellfield areas is inhibited by low water availability and exposure to strong winds causing high desiccation stress in the plants. While several nitrophilous lichen taxa constitute distinct communities in habitats influenced by penguin colonies, fellfield species do not appear to be influenced by high concentrations of specific nutrients. Exposure data (as mean evaporation) along the transect on 30 and 31 December 1985 are given in Table 1.

While the change in community composition described for Site 4 occurs over a distance of 16 m and a vertical height of 1.5 m, comparable gradients are often on a much smaller scale. Site 5 (Fig. 6) is only a few meters from Site 4 but rises only *ca.* 30 cm at about 3 m from the margin of the same melt stream. The distribution and association of species is similar to those at Site 4 but with a preponderance of liverwort

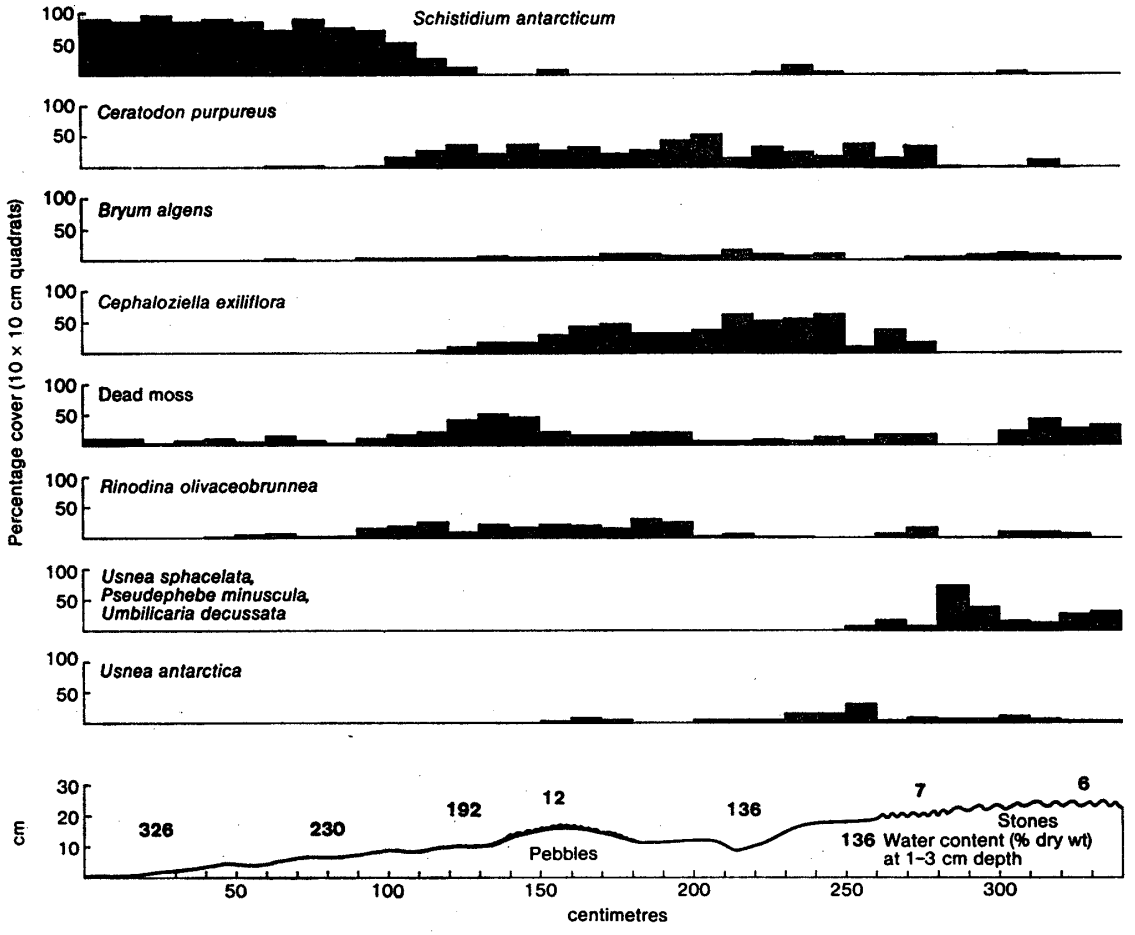

Fig. 6. Site 5. Distribution and percentage cover of principal species along a gradient from hydric to xeric soil conditions at the margin of a seepage channel near the outflow from a melt lake. The water contents of the moss or soil surface are given at intervals along the transect.

in a central moist depression.

Depressions in boulder-fields (*e.g.* Site 6, Fig. 7) accumulate deeper drifts of winter snow and also are quickly filled by snow during summer blizzards. Being relatively sheltered and receiving a more regular supply of moisture during summer, these hollows support stands of moss, particularly a tall turf of *Ceratodon purpureus*, the surface of which, through the action of freeze-thaw cycles, becomes convoluted into a network of ridges and troughs. The moss on the more exposed ridge crests is killed and becomes colonized by cyanobacteria and the encrusting lichen *Rinodina olivaceobrunnea*. In the moister sheltered troughs *Bryum algens* and *Cephaloziella exiliflora* are usually frequent; occasionally *Usnea antarctica* forms tall dense epiphytic mats on the deeper moss turf. The slope of the hollow becomes increasingly drier towards the rim and the moss turf becomes progressively shorter, more cracked and encrusted by lichens. There is a sharp transition to the typical *Usnea-Pseudephebe-Umbilicaria* fellfield on the windswept terrain at and beyond the margin of the hollow. Soil or plant moisture contents at intervals along the transect are given in Fig. 7.

Changes in the chemistry of a soil profile in the moist hollow and dry slope are shown in Table 3. For most elements, concentrations are very much higher in the moist

Table 2. Soil chemical

Position on transect and depth (cm)			Moisture content (% dry wt)	pH	Na (ppm)*	K
Crest of knoll						
Usenea sphacelata	thalli		—	—	710	1700
	soil	0–1.5	18	5.42	770	290
	soil	1.5–3.0	14	6.18	480	330
	soil	5.0–9.0	11	5.55	250	170
Terrace						
Ceratodon-Rinodina	turf	0–1.5	20		560	860
	peat/soil	1.5–3.0	15	6.76	210	110
	soil	3.0–5.0	7	5.62	100	110
	soil	5.0–7.0	7	5.95	41	99
Margin of wet hollow						
Ceratodon-Bryum	truf	0–1.5	354	—	810	3400
	turf	1.5–3.0	326	—	610	1400
	peat	3.0–5.0	230	5.11	170	250
	peat	5.0–7.0	217	4.13	210	270
Wet hollow						
Schistidium	turf	0–1.5	395	—	1000	4500
	turf	1.5–3.0	468	—	660	4100
	peat	3.0–5.0	470	5.11	270	580
	peat	5.0–7.0	500	5.29	290	350
	peat	7.0–9.0	396	5.40	300	110

* Data for lichen thalli and moss turf determined as total element (%) while those for peat and soil have been converted to parts per million (*i.e.* $\% \times 10^4$ ppm; mg/100 g$\times$ 10 ppm).

Table 3. Soil chemical

Position on transect and depth (cm)			Moisture content (% dry wt)	pH	Na (ppm)*	K
Dry upper slope of hollow						
Ceratodon-Rinodina	turf	0–1.5	83	—	2900	3300
	peat	1.5–3	63	5.60	660	1260
	peat	3–4.5	52	5.64	470	410
	soil	4.5–6	26	5.62	190	230
	soil	6–8	17	5.50	58	140
	soil	8–11	16	5.20	59	96
	soil	11–14	11	5.08	66	180
	soil	4–17	7	4.81	40	110
	soil	17–20	8	5.15	72	200
	soil	20–23	10	4.96	49	110
Moist center of hollow						
Ceratodon	turf	0–1.5	121	—	740	3600
	turf	1.5–3	171	—	530	1200
	turf	3–4.5	226	—	620	1300
	turf	4.5–6	245	—	670	1400
	peat	6–9	250	5.19	290	300
	peat	9–12	175	5.28	220	200
	peat	12–15	105	5.18	130	100
	peat	15–20	76	5.15	100	88

* Data for moss turf determined as total element (%) while those for peat and soil determined as verted to parts per million (*i.e.* $\% \times 10^4$ ppm; mg/100 g$\times$ 10 ppm).

analysis at Site 4.

Ca	Mg	Mn	Fe	Al (ppm)*	P	NH_4-N	NO_3-N	Total N
300	460	30	1700	930	630	—	—	3700
1300	400	5.4	5800	2300	4200	77	38	—
1100	250	3.3	4900	1400	4600	50	20	—
790	96	1.3	5200	2200	6100	11	6.9	—
980	930	13	4840	1680	230	50	2.3	—
120	31	1.3	5800	2300	1200	16	0.3	—
440	190	6.1	5700	2200	420	12	0.9	—
170	60	1.8	8300	2700	750	8.5	0.5	—
3800	1800	60	1300	830	1700	—	—	8100
4600	1900	120	5200	5400	2400	—	—	14000
1230	1110	18	3490	1440	520	130	2.9	—
970	630	13	4680	2250	440			
4600	2100	60	530	470	1700	—	—	9100
5500	2200	100	2800	8400	1700	—	—	10000
1800	1500	33	8890	4570	—	—	4.6	—
2050	1730	59	9220	1160	190	89	2.1	—
2210	1410	32	2730	2850	26	—	1.0	—

determined as extractable element (mg/100 g dry wt). For comparative purposes both data sets

analysis at Site 5.

Ca	Mg	Mn	Fe	Al (ppm)*	P	NH_4-N	NO_3-N	Total N
3900	2200	150	6300	3600	3400	—	—	13000
970	580	8.8	9130	4690	450	62	3.8	—
470	380	12	4930	2610	88	27	1.7	—
420	380	8.7	4910	1700	260	25	1.0	—
87	19	2.0	10000	3500	440	4.5	0.3	—
140	38	0.5	6100	2400	87	4.5	0.2	—
110	21	0.5	13000	4500	620	2.5	0.4	—
48	5	0.5	10000	3700	130	3.5	0.5	—
84	11	0.5	11000	4900	450	9.3	0.5	—
48	5	0.5	10000	3700	130	3.5	0.5	—
4100	2100	120	3500	1600	2000	—	—	6100
5100	2100	1500	4600	2900	1400	—	—	6100
5400	2300	200	6500	3500	1400	—	—	6900
5700	2500	220	7600	4200	2100	—	—	10000
2100	1300	57	4660	3140	66	92	1.5	—
1400	960	44	5590	3870	52	58	1.1	—
910	470	23	6240	3810	130	26	0.1	—
780	350	18	6490	3430	74	11	0.1	—

extractable element (mg/100 g dry wt). For comparative purposes both data sets have been con-

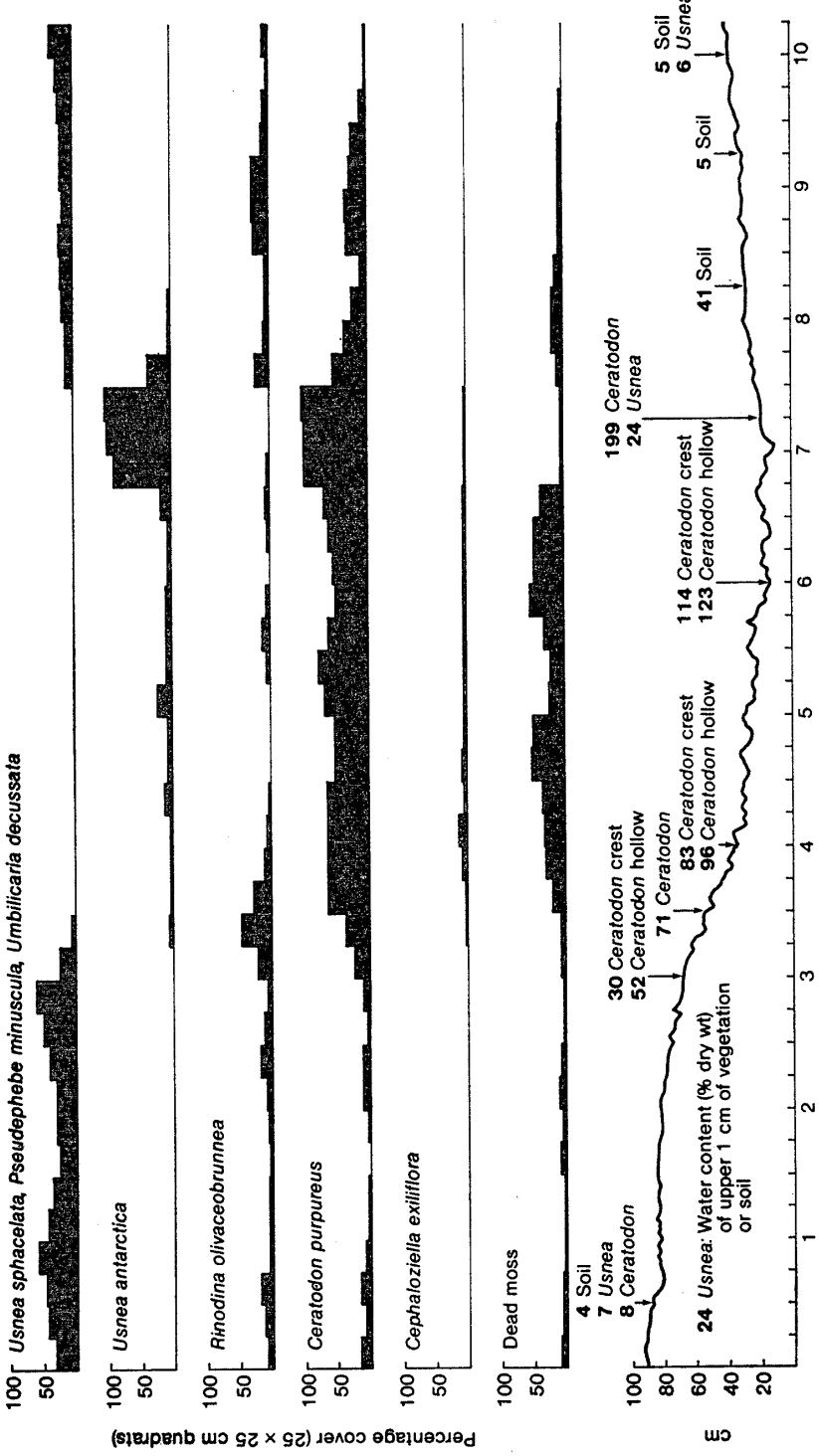

Fig. 7. Site 6. Distribution and percentage cover of principal species along an exposure-moisture gradient across a depression with lichen-dominated stony ground around it. The water contents of the soil or moss surface are given at intervals along the transect.

moss peat in the hollow than in the dry peat and mineral soil higher up the slope. While biotically-derived nutrient input at this site is minimal, the moist peat serves as a sink for nutrients transported in melt water and wind-borne dust. The shelter afforded by the depression, the increased moisture, and apparently non-limiting levels of nutrients have permitted a relatively luxuriant growth of moss and the accumulation of 10–20 cm of peat. Although minimal microfauna were recorded (a few occurrences of protozoans, tardigrades, and nematodes but no micro-arthropods were seen, although *Nanorchestes antarcticus* is known from this area), there is clearly an active microbial community responsible for the partial decomposition of the moribund moss turf. Aspects of the thermal characteristics of this site have been described by SMITH (1988b), who demonstrated exceptional diel changes of over 50°C within the drier moss turf, and discussed the significance of desiccation and heat stress in the water relations and metabolic rates of these plants (see also KAPPEN *et al.*, 1989). Relative exposure at various positions along the transect is shown in Table 1.

Even within individual moss stands water content can vary dramatically over short distances. A large (*ca.* 10×6 m) closed *Ceratodon* turf on a very gentle gravelly slope near Whitney Point, Clark Peninsula, extends from the margin of a late snow bed. When examined on 1 January 1986, the moss turf adjacent to remnants of the melting snow patch was fresh and green, but with increasing distance from the source of water the turf became progressively darker brown, drier, and more cracked. At the dry end of this hydrological gradient, the turf was broken up into polygonal units of about 10–20 cm across and separated by fissures up to 3 cm wide; each unit was detached from the stony substratum. Water contents of the turf at 2–5 cm depth taken at 1 m intervals were 598% (of dry wt) 1 m from the snow patch, 231% at 2 m, 223% at 3 m, 171% at 4 m, and 10% at 5 m and 8 m. During brilliant sunshine, the temperature of the moss 1 cm below the surface ranged from 8°C 1 m from the snow to 32°C 5 m away.

Small-scale environmental zonation is exhibited in networks of patterned ground. Well-developed polygon and soil circle features are widespread on terrain recently exposed by receding ice fields, implying that they had been formed during an earlier phase of deglaciation and survived intact during a recent period of increased ice cover. However, periglacial features close to retreating ice are still in the stage of primary colonization with *Ceratodon purpureus* and *Rinodina* spp. being the predominant terricolous species. Older features exhibit a distinct zonation of species around the polygons related to the microtopography and texture of the substratum. The vertical amplitude of these features is seldom more than 10–15 cm. Sites 7 and 8 (Fig. 8a, b) are typical of mature but only weakly sorted circles in which the established vegetation has undergone erosion by wind action in areas subjected to frost heaving within the circle. Outside many of these features is a lower area of soil, gravel, and stones which retains melt water and supports small closed moss carpets, mainly of *Schistidium antarcticum*, and sometimes small mats of *Cephaloziella exiliflora*. Thus the outer circle of coarse raised stones and, at Site 7, the smaller sorted pebbles of a subsidiary inner circle, are colonized by fruticose lichens, especially *Usnea sphacelata* and *Pseudephebe minuscula*. The peripheral stone "wall" affords some protection to the central depressed area which has a dense cover of short *Ceratodon*. Although this moss is frequent across the feature, the central area has a high cover of dead moss indicating a former healthy stand which may have

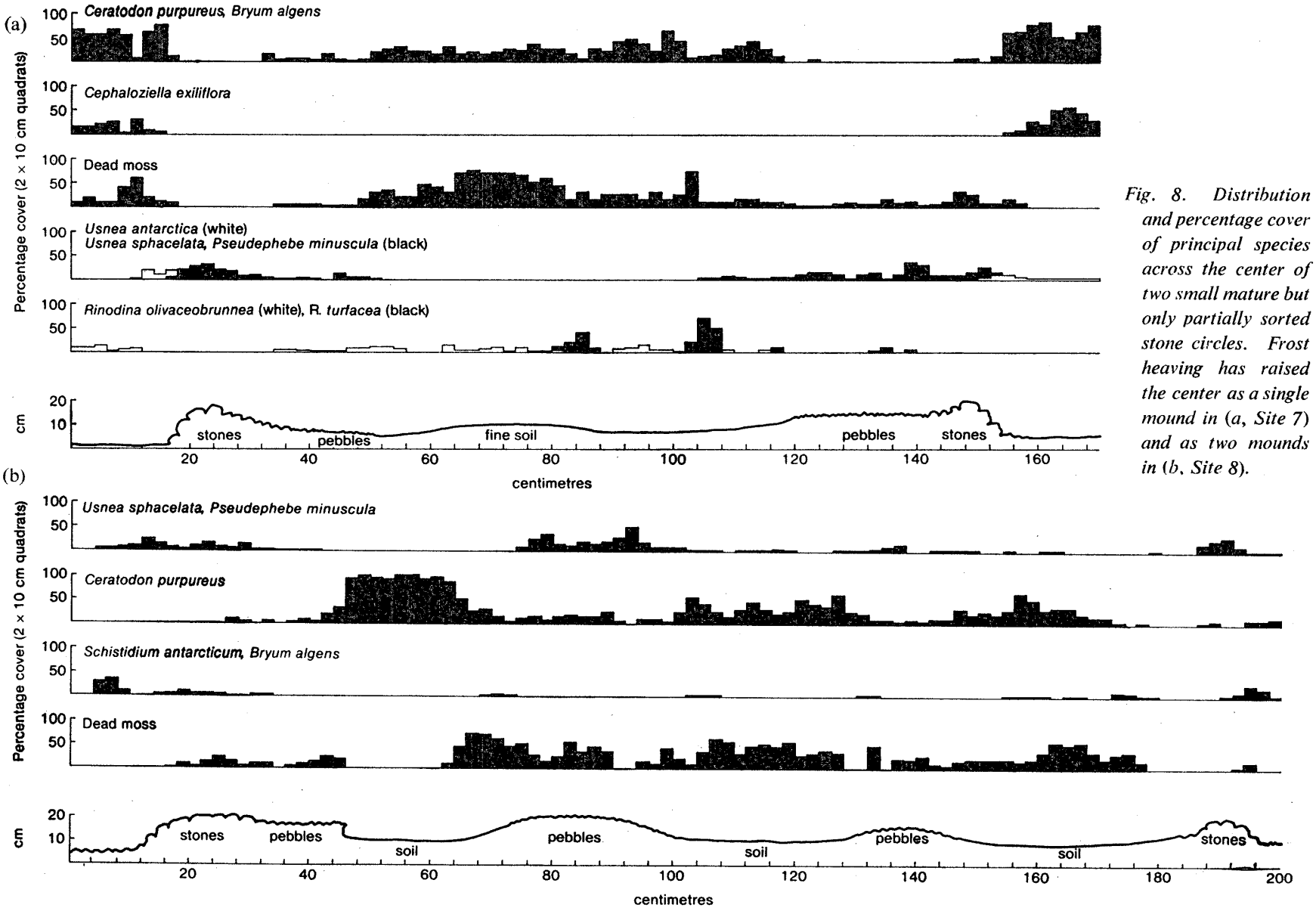

Fig. 8. Distribution and percentage cover of principal species across the center of two small mature but only partially sorted stone circles. Frost heaving has raised the center as a single mound in (a, Site 7) and as two mounds in (b, Site 8).

existed *in vivo* at a time when the center was lower and more sheltered; subsequently, the inner section of the stone circles may have risen during the spring thaw and fallen later in the season. Abrasion by wind-driven soil or ice particles may kill much of the living moss each year during the early phase but regeneration later in the season increases the living biomass when this ground has subsided.

4. Discussion

By comparison with many other continental Antarctic areas, conditions on Bailey and Clark Peninsulas are favorable enough to have induced a relatively stable, complex, and well-developed vegetation. The unusually extensive bryophyte vegetation in this region probably results from a combination of environmental features, of which the most important are likely to be the locally abundant supplies of melt water during the short cold growing season, relatively stable and widespread deposits of glacial till, and possible nutrient enrichment (especially P) from large numbers of sub-fossil penguin colonies.

The predominant community type, dominated by three bipolar macrolichens (*Usnea sphacelata*, *Pseudephebe minuscula*, and *Umbilicaria decussata*), is the most widespread plant assemblage throughout Antarctica, and many other components of the cryptogamic flora have a circum-Antarctic distribution. The bryophyte communities are dominated by three of the most widely distributed circum-Antarctic mosses (*Bryum algens*, *Ceratodon purpureus*, *Schistidium antarcticum*). *C. purpureus* is one of the most cosmopolitan of all plant species, as is *Bryum pseudotriquetrum* (with which *B. algens* may be synonymous).

The terrestrial vegetation of the Bailey Peninsula SSSI comprises relatively few species (three mosses, one liverwort, *ca.* 23 lichens) arranged into a number of closely related and integrated noda in a continuum of variation (SMITH, 1988a). Absence of a clearly defined hierarchical system of communities results from the paucity of species, especially those capable of achieving dominance, a lack of diversity of habitat types, and a small range of environmental variables, most of which are a feature of microclimate. However, specific associations of bryophytes and lichens occur wherever a similar suite of environmental criteria prevails. This study has confirmed the findings of several other workers (*e.g.*, SMITH, 1972, 1984; NAKANISHI, 1977; SHIMIZU, 1977; YAMANAKA and SATO, 1977; PICKARD, 1986; SELKIRK and SEPPELT, 1987; KANDA, 1987), namely that the distribution of Antarctic cryptogam species and communities is intimately related to environmental criteria. In the stressful environment of the Antarctic the most successful species both ecologically and physiologically are those adapted to tolerate the often rapidly fluctuating spatial and temporal conditions that the plants experience. However, while those species with a wide ecological amplitude are generally not restricted in their distribution, many individual species are sensitive to minor differences in edaphic, hydrologic, microtopographic, and microclimatic features of the habitat. This is commonly expressed in terms of sharp changes in species dominance and in community structure over very short horizontal and vertical distances. This creates distinct ecological patterns within the more complex terrestrial ecosystem of this region of continental Antarctica.

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